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Guillermo L. Albanesi and Gladys Ortega

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MIDDLE ORDOVICIAN CONODONTS AND GRAPTOLITES AT LOS CAUQUENES RANGE, CENTRAL PRECORDILLERA OF SAN JUAN, ARGENTINA

VOLDMAN, G. G.[1, 2], ORTEGA, G [1] AND ALBANESI, G. L. [1, 2]

[1] CONICET-Museo de Paleontología, CIGEA, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, X5000JJC, Córdoba, Argentina; *gvoldman@efn.uncor.edu, gcortega@arnet.com.ar, galbanes@com.uncor.edu*
[2] CICTERRA-CONICET, Córdoba, Argentina.

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THE Ordovician System is superbly represented in the Precordillera of western Argentina, at the Andean foothills. During the Middle Ordovician, an important paleogeographical rearrangement of depocenters and source areas took place associated with the demise of the Eopaleozoic carbonate platform of the Precordillera. This critical interval is recorded in the basin through widespread deposition of black shales over the fossiliferous limestones of the San Juan Formation, punctuated by local deposition of olistostromes, debris flows, conglomerates, and turbidites (*e.g.*, Astini *et al.*, 1995; Keller, 1999). Fossil dating of the lowest black shales and equivalent units indicates a diachronous deposition from north to south in the Precordillera basin (Hünicken, 1985; Albanesi *et al.*, 1998).

The occurrence of Ordovician clastic rocks in the Jáchal area is known since the study of Borrello and Gareca (1951), who recorded *Nemagraptus gracilis* (J. Hall) in the Ordovician upper shaly succession that is exposed in the western flank of the Cerro Viejo, a prominent mountain situated midway between Huaco and Jáchal city. Harrington (in Harrington and Leanza, 1957) distinguished two formations in the lower and upper parts of this succession, the Cerro Viejo Shales and Los Azules Shales, respectively. Furque (1979) referred all the Ordovician clastic sequence to the Los Azules Formation, equivalent to the Gualcamayo Formation elsewhere. Later, Ortega (1987) refined the biostratigraphy of the Los Azules Formation by determining a lower member, made up of dark claystones and siltstones interbedded with K-bentonites (lower Darriwilian), a middle member that consists of black shales and siltstones (upper Darriwilian), and an upper member of yellowish calcareous siltstones and calcarenites (upper Sandbian). A hiatus covering the highest Darriwilian and the lowest Sandbian is recorded between the middle and upper members.

The Los Azules Formation is arranged in small isolated outcrops aligned in narrow elongated belts with meridian orientation. The best exposures of the Los Azules Formation are located at the foothill of the Cerro Viejo, between 30º 11' 40" and 30º 15' 30" S Latitude, and 68º 34'30" and 68º 35'20" W Longitude, uplifted by the Niquivil Thrust (*e.g.*, Ortega *et al.*, 2007). It also crops out along western thrusts in the less studied successions of the La Chilca, Mogotes Azules, and the Aguada de Los Azulejitos on the northernmost Talacasto Range.

The purpose of this paper is to describe for the first time a restricted stratigraphic exposure that bear a significant conodont and graptolite fauna of the upper section of the San Juan Formation and the overlying the Los Azules Formation (Fig. 1), which is currently under study. The stratigraphic section is located at the Los Cauquenes Range, a parallel thrust belt to the Cerro Viejo de Huaco thrust. The latter thrust belt is 4 km to the east, where the Los Azules Creek, the type section of the homonymous formation, is located.

At the Oculta Creek, the upper levels of the San Juan Formation are characterized by nodular limestones, which are highly fossiliferous. These are roofed by a hardground surface, rich in nautiloids at the contact with the Los Azules Formation, which is interpreted as a marine flodding surface (Astini, 1994).The Los Azules Formation presents 226 m in thickness at the Oculta Creek, with the lower, middle and upper members well developed. It is unconformably overlain through angular

discordance by Holocene alluvial fan deposits. The Los Azules Formation starts with dark-brown argillites with yellowish alteration and concoidal fracture interbedded with K-bentonites. The middle member consists of black-grey shales and siltstones, and the upper member is made up of calcareous siltstones of dark colour and yellow alterations, with scarce mudstones strata intercalated, some of them reaching up to 1 m.

In order to define the age of aforementioned strata by conodont dating, we took 3 rock samples from the uppermost levels of the San Juan Formation (4.5 kg) and 2 rock samples from the base of the Los Azules Formation (3 kg).The samples are condensed limestone deposits, which after digesting in 10% acetic acid following the conventional procedures, produced over 2200 conodont elements. The collected specimens are well preserved and exhibit a CAI 2 (Epstein *et al.*, 1977). These are stored in the Museo de Paleontología, Universidad Nacional de Córdoba, under repository code CORD-MP.

The conodont collection exhibits a high species diversity (Fig. 2), including *Ansella jemtlandica* (Löfgren), *Baltoniodus* sp.,

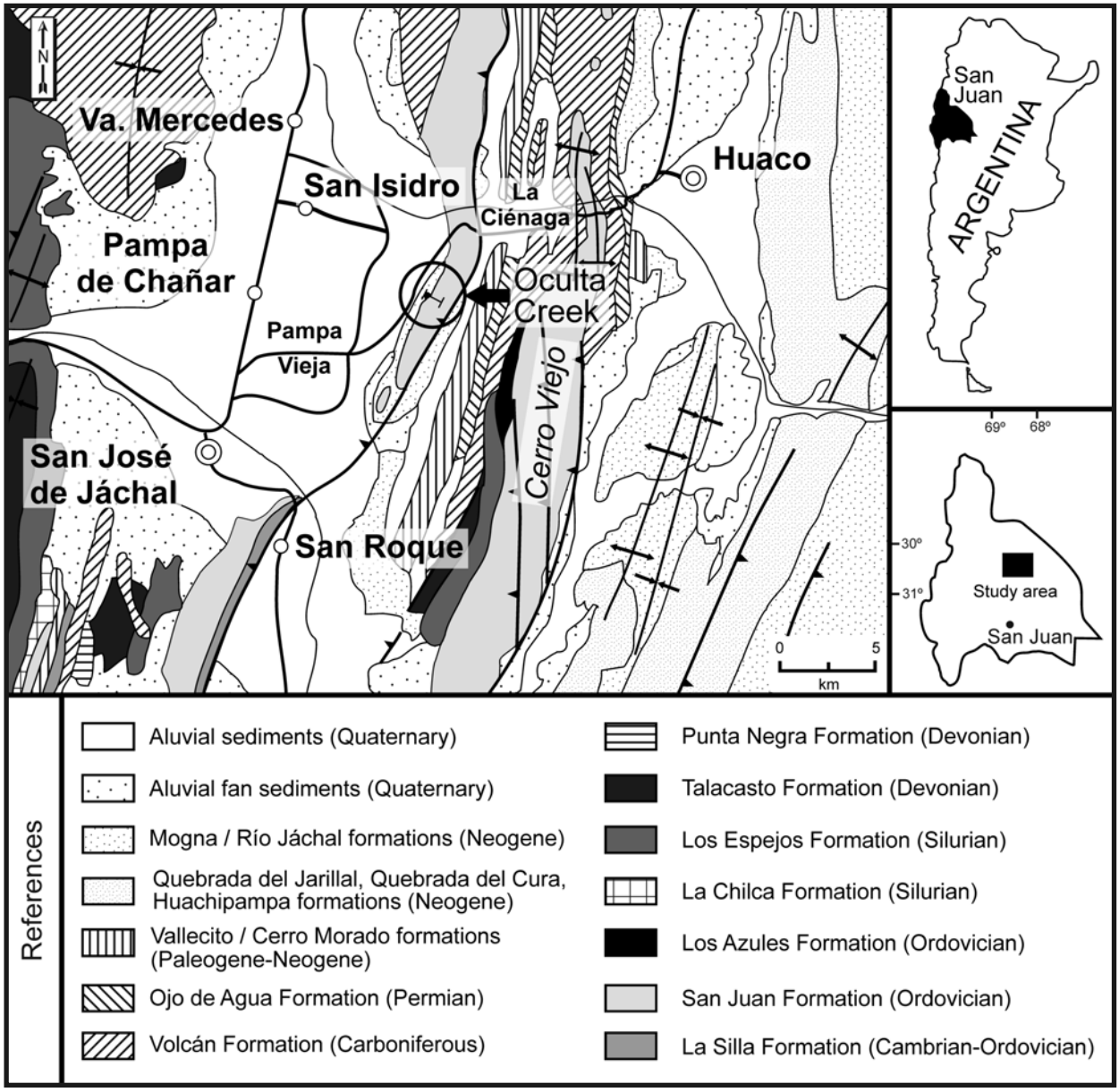

Figure 1. Geological map with the location of the Oculta Creek, Central Precordillera, San Juan Province, Argentina (modified from Furque, 1979, Furque *et al.*, 1998).

Figure 2. Darriwilian (*Yangtzeplacognathus crassus* Zone, Da2) conodonts from the Oculta Creek, Central Precordillera, San Juan Province, Argentina. **1, 7, *Drepanodus arcuatus*** Pander. **1**, Pb element, CORD-MP28039, **7**, Sa element, CORD-MP28045; **2, *Cornuodus longibasis*** (Lindström), Sd element, CORD-MP 28040; 3, ***Ansella jemtlandica*** (Löfgren), M element, CORD-MP 28041; **4, *Protopanderodus calceatus*** Bagnoli and Stouge, P element, CORD-MP 28042; ***5, 12, 15***, ***Yangtzeplacognathus crassus*** (Chen and Zhang). **5,** Pb element,antero-lateral view, CORD-MP28043, **12**, Sa element, upper view, CORD-MP 28050, **15**, Pa element, upper view, CORD-MP28053; **6**, ***Parapaltodus simplicissimus*** Stouge, M element, CORD-MP 28044; ***8–9***. ***Periodon*** n. sp. **8**, M element, CORD-MP 28046, **9**, Pa element, CORD-MP 28047; **10, *Semiacontiodus potrerillensis*** Albanesi, long based coniform, CORD-MP 28048; **11**, ***Paroistodus horridus*** (Barnes and Poplawski), Sc element, CORD-MP28049; **13**, ***Microzarkodina hagetiana*** Stouge and Bagnoli, M element, CORD-MP28051; **14**, ***Histiodella holodentata*** Ethington and Clark, Pa element, CORD-MP28052; **16**, Gen. et sp. indet., CORD-MP28054; **17**, ***Pteracontiodus cryptodens*** (Mound), M element, CORD-MP28055; **18**, ***Periodon macrodentatus*** (Graves and Ellison), M element, CORD-MP28056; **19, *Erraticodon alternans*** (Hadding), Pb element, CORD-MP28057; **20**, ***Drepanoistodus bellburnensis*** Stouge, M element, CORD-MP28058; **21**, ***Fahraesodus marathonensis*** (Bradshaw), Sa element, CORD-MP 28059; **22**, ***Drepanoistodus costatus*** (Abaimova), Sa element, CORD-MP 28060; **23, *Costiconus costatus*** (Dzik), Sb element, CORD-MP 28061; **24, "Bryantodina"** aff. ***typicalis*** Stauffer, Pa element, CORD-MP 28062; ***25***, ***Drepanoistodus tablepointensis*** Stouge, M element, CORD-MP 28063. All illustrated specimens proceed from sample TFSJ1º hrdgrnd. All elements show inner-lateral views except where indicated. Scale bar: 0.1 mm.

"Bryantodina" aff. *typicalis Stauffer*, *Cornuodus longibasis* (Lindström), *Costiconus costatus* (Dzik), *Drepanodus arcuatus* Pander, *D. reclinatus* (Lindström), *Drepanoistodus bellburnensis* Stouge, *D.costatus* (Abaimova), *D.forceps* (Lindström), *D. tablepointensis* Stouge, *Erraticodon alternans* (Hadding), *Fahraesodus marathonensis* (Bradshaw), *Histiodella holodentata* Ethington and Clark, *Microzarkodina hagetiana* Stouge and Bagnoli, *Parapaltodus simplicissimus* Stouge, *Paroistodus originalis* (Sergeeva), *Paroistodus horridus primus* Albanesi, *P. h. secundus* Albanesi, *P. horridus horridus* (Barnes and Poplawski), *Periodon macrodentatus* (Graves and Ellison), *Protopanderodus calceatus* Bagnoli and Stouge, *Pteracontiodus cryptodens* (Mound), *Scolopodus striatus* Pander, *Semiacontiodus potrerillensis* Albanesi and the index species *Yangtzeplacognathus crassus* (Chen and Zhang). It also includes a new species of *Periodon* and a Gen. et sp. indet. This conodont association allows constraining the uppermost levels of the San Juan Formation and the lower levels of the Los Azules Formation to the *Yangtzeplacognathus crassus* Zone of early middle Darriwilian age (Da2) (Fig. 3), following the Baltoscandic and Chinese schemes (Zhang, 1998; Löfgren and Zhang, 2003). This is consistent with the timing of the drowning of the San Juan Formation in the nearby Cerro Viejo de Huaco (Ortega *et al.*, 2007), as well as Los Blanquitos and La Trampa ranges, central area of the Precordillera (Albanesi *et al.*, in press). In Laurentia, this interval correlates with *Histiodella holodentata* Subzone of the *Periodon macrodentatus* Zone (Stouge, 2012). The studied conodont assemblage is accompanied by sponge spicules, brachiopods, foraminifers and gastropods.

On the other hand, the argillites of the lower member of the Los Azules Formation contain a rich graptolite association referable to the early middle Darriwilian *Levisograptus dentatus* Zone. It is composed of *Tetragraptus quadribrachiatus* (J. Hall), *Pseudotrigonograptus ensiformis* (J. Hall), *Xiphograptus lofuensis* Lee, *Acrograptus* sp., *Holmograptus bovis* Williams and Stevens, *Isograptus* cf. *victoriae divergens* Harris, *Parisograptus caduceus* (Salter), *Arienigraptus* sp., *Paraglossograptus tentaulatus* (J. Hall), *Levisograptus austrodentatus* (Harris and Keble), *L.* cf. *dentatus* (Brongniart), *L. sinicus* (Mu and Lee) and *L. primus* (Legg). The stratigraphic contact of the lower member with the black-grey shales and siltstones of the middle member is partially splintered and covered. The latter member hosts a significant graptolite fauna corresponding to the *Pterograptus elegans* Zone, just above the deformed levels. The overlying levels are dominated by biserial graptolites that represent the *Hustedograptus teretiusculus* Zone, following Ortega (1987). This way, the middle member is late Darriwilian in age, yet the temporal definition of its lower limit is hampered by the pervasive deformation of the stratigraphic levels. The upper member of the Los Azules Formation includes graptolites of the *Climacograptus bicornis* Zone (late Sandbian) characterized by the presence of the nominal taxon associated with *Nemagraptus gracilis, Cryptograptus tricornis* (Carruthers), *Glossograptus ciliatus* (Emmons) and a variety of dicranograptids, and biserial graptolites.

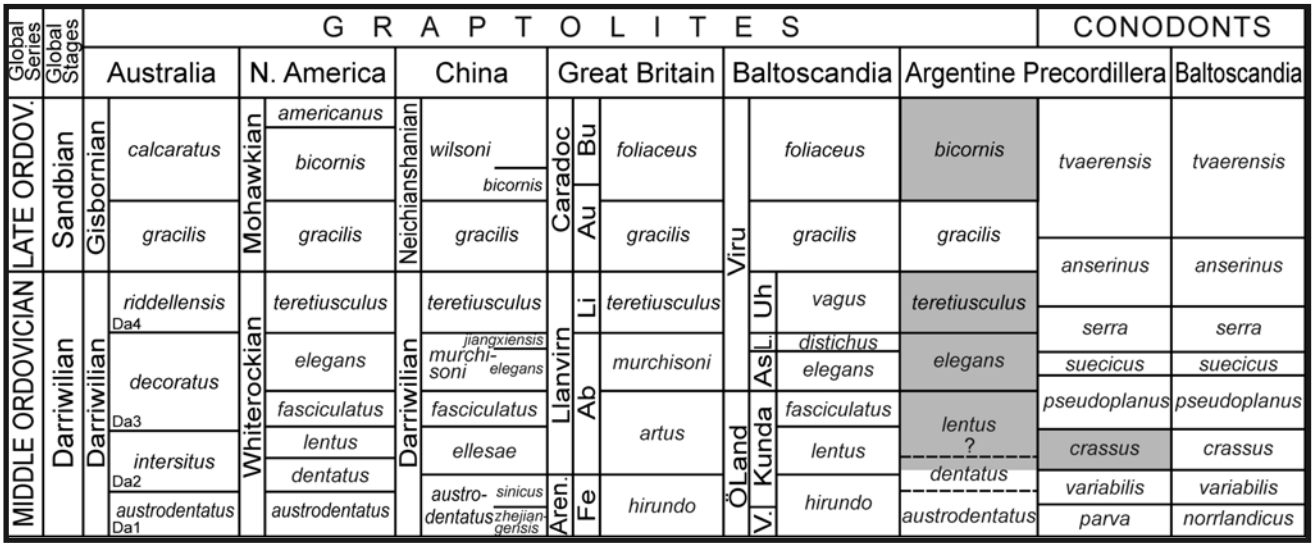

Figure 3. Biostratigraphic chart for conodonts and graptolites of the Argentine Precordillera and correlation with reference schemes [modified from Webby *et al.* (2004), Ortega *et al.* (2007), and Maletz *et al.* (2009)].

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